Pacific Island Network
Vital Signs Monitoring Plan

Appendix A: Haleakala National Park Resource Overview

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Pacific Island Network (PACN)

Territory of Guam
War in the Pacific National Historical Park (WAPA)

Commonwealth of the Northern Mariana Islands
American Memorial Park, Saipan (AMME)

Territory of American Samoa
National Park of American Samoa (NPSA)

State of Hawaii
USS Arizona Memorial, Oahu (USAR)
Kalaupapa National Historical Park, Molokai (KALA)
Haleakala National Park, Maui (HALE)
Ala Kahakai National Historic Trail, Hawaii (ALKA)
Puukohola Heiau National Historic Site, Hawaii (PUHE)
Kaloko-Honokohau National Historical Park, Hawaii (KAHO)
Puuhonua o Honaunau National Historical Park, Hawaii (PUHO)
Hawaii Volcanoes National Park, Hawaii (HAVO)

http://science.nature.nps.gov/im/units/pacn/monitoring/plan/

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EXECUTIVE SUMMARY & INTRODUCTION

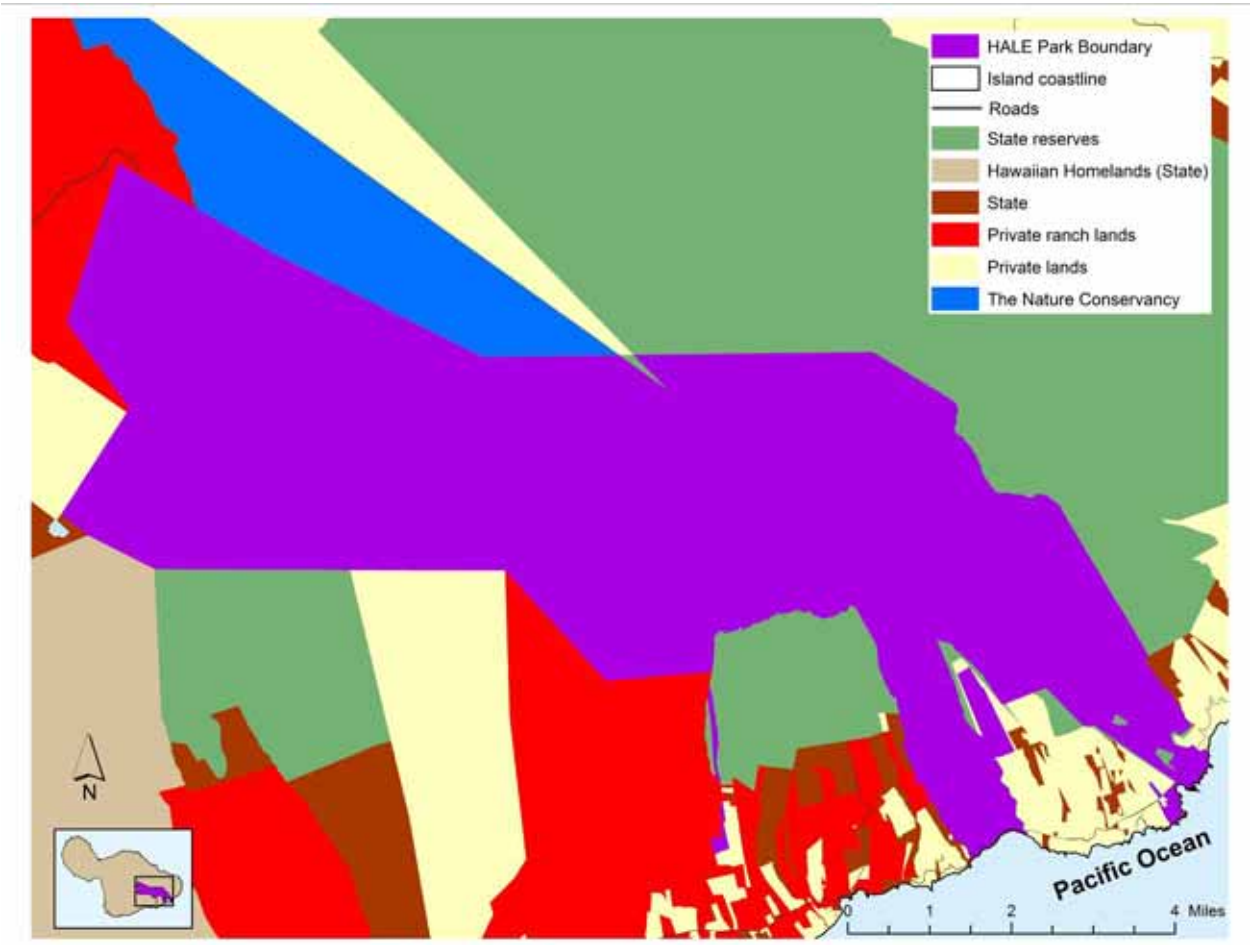
Enabling Legislation

Enabling legislation to establish a national park in the Territory of Hawaii was approved August 1, 1916 (39 Stat. 432). The enabling legislation (16 USC 391) for Hawaii National Park states that it *"...shall be perpetually dedicated and set apart as a public park or pleasuring ground for the benefit and enjoyment of the people of the United States…and provide for the preservation from injury of all timber, birds, mineral deposits and natural curiosities or wonders within said park, and their retention in their natural conditions as nearly as possible.*" Effective July 1, 1961, the Haleakala Section of Hawaii National Park on the island of Maui was established as a separate unit and to be administered in accordance with the NPS Organic Act (39 Stat. 535 and with any other applicable provisions of the law relating to the Maui section of Hawaii National Park (16 USC 396).

To find enabling legislation documents on-line follow the "Policy & Legislation" link from the Pacific Island Network website (www1.nature.nps.gov/im/units/pacn).

Geographic Setting

Haleakala National Park (HALE) is located on east Maui which includes the summit of Haleakala volcano (10,023 feet) and extends eastwards to sea level at Oheo and Kaapahu (see map below). Haleakala covers 30,183 acres and is divided into two districts. The Summit District includes the crater area, portions of its outer slopes, and the upper sections of the Kaupo and Koolau gaps. The wetter Kipahulu District includes Kipahulu Valley, Manawainui and Kaumakani planezes, upper Hana rain forest, Oheo /Puhilele coastal areas, and the 1999 Kaapahu addition. The majority of the park is designated as wilderness. Adjacent land owners include Haleakala Ranch, Kaupo Ranch, East Maui Irrigation Company (EMI), Waikamoi Preserve (managed by the Nature Conservancy of Hawaii), the State of Hawaii (Hanawï Natural Area Reserve and State Forest Reserves), and small private land owners. The majority of land use surrounding the park includes ranching on private lands and conservation on lands managed by members of the East Maui Watershed Partnership. Adjacent to the summit area is "Science City," a multi-institutional collection of observatories and antennas located on state land just southwest of the park. Maui's population (ca. 110,000 people) is concentrated near leeward coastal areas far from the park; fewer than 1,500 people live within 5 miles of the park.



Significant Natural and Cultural Resources

The Haleakala Section of Hawaii National Park was established for its scenic and geological features, primarily Haleakala Crater. Since becoming its own national park, Haleakala's biological resources have gained special attention within the scientific community. The park harbors a rich assemblage of native plant and animal communities with tremendous species diversity. Ecosystems include an alpine cinder desert, sub-alpine shrublands, sub-alpine grasslands, montane bogs and ponds, perennial and intermittent streams, cloud and rain forests, mesic forest, and coastal strand. The Oheo / Puhilele and lower Kaapahu areas exhibit altered natural ecosystems targeted for restoration through select alien plant control, and native and Polynesian- introduced plantings. Haleakala is home to 26 federal threatened and endangered species (TES) with 15 TES candidates and 57 Species of Concern (USFWS 1973).

Many areas within Haleakala are culturally and spiritually important to native Hawaiians. These areas have been used by Hawaiians for a wide range of activities from pre-

European contact (before 1779) to the present day. Haleakala contains a wide variety of Hawaiian and non-Hawaiian tangible cultural resources. Although only a limited number of cultural resource studies have been conducted within Haleakala to date, it is known that the park contains numerous archeological resources, historic structures, museum objects, cultural landscapes, and ethnographic resources. Many of these cultural resources are located within two historic districts. The Crater Historic District is listed in the National Register of Historic Places (NRHP) and encompasses all of Haleakala Crater. The Kipahulu Historic District encompasses the lower portions of Kipahulu Valley, former pasture lands, and the Oheo/ Puhilele coastal areas.

Resource Management Priorities

Resource management priorities identified in the General Management Plan (1995) are 1) to re-establish and perpetuate (as nearly as possible) the mosaic of ecosystems which would have evolved without interference of human technology, 2) to protect and restore native biota by controlling non-native plants and animals, particularly aggressive species which out-compete native forms, 3) to isolate and carefully restrict use of the upper Kipahulu Valley to ensure the perpetuation of nearly pristine native flora and fauna, 4) to maintain the human altered Kipahulu coastal area in its present state with latitude for restoration of native plant communities (where appropriate), 5) to identify and protect cultural sites and remains, stabilize significant archeological structures and where appropriate, assist in the perpetuation and interpretation of traditional Hawaiian culture, and 6) to encourage a comprehensive park research program for improvement of management and interpretation of Haleakala's geologic, biotic, and cultural values.

NATURAL RESOURCES

Focal Ecosystems and Processes

Haleakala National Park includes several unique ecosystems that provide contrasting environmental conditions, rare and endangered species, and beautiful natural scenery.

- ***Rainforest/Cloud forest***: The rain and cloud forests of Haleakala National Park are among the richest and most ecologically intact in Hawaii. Nevertheless, rainforest habitat, especially mid-elevation forest, is seriously threatened by alien species. Due to their inaccessibility, the high elevation cloud forests of East Maui have been less impacted by human activities and alien species than lower elevation forests. In the upper Kipahulu Valley, more than 95% of native species are endemic. To protect this almost pristine native forest it has been closed to public entry. However, the impacts of climate change could be devastating for these extremely sensitive ecosystems.
- ***Bogs and Ponds***: There are 15 endemic plant species that are largely confined to bog habitat. The bogs of Haleakala offer unique opportunities for the study of evolutionary patterns. Fencing has kept feral pigs (*Sus scrofa*) out of the bogs, saving this limited habitat from destruction. However, climate change (reduced rainfall) could destroy this unique ecosystem (Loope 1991a, 1995a, 1995b). Three small high

elevation ponds, Waianapanapa, Wai Nene and Waieleele, are located within the bog habitat.

- ***Streams***: Haleakala contains some of the highest quality streams remaining in the state of Hawaii, as well as the largest undiverted streams. These streams provide habitat to several native fish and mollusks, crustaceans, and insects. The Koukouai stream is eligible for designation as national Wild and Scenic Rivers. Puaaluu stream (on the border of Haleakala) has been included in The Nature Conservancy's national list of "Priority Aquatic Sites for Biodiversity Conservation". The park also contains waterfalls listed in the Hawaii Stream Assessment's "Hawaii's Waterfalls" list.
- ***Grasslands***: Unique *Descampsia* grasslands exist in the upper elevations of Haleakala.
- ***Mesic forest***: Large tracts of the mesic forest vegetation in Haleakala have been lost as a result of feral animal damage and human impacts such as fire, logging, and grazing. However, a few patches with rare mesic montane forest species remain in the Kaupo Gap area. The Kaapahu area contains mesic forest areas that were heavily impacted by logging and feral animals. Efforts are underway to protect these forests by reducing the number of feral animals and by restoring native plants thru re-vegetation efforts.
- ***Alpine/ Aeolian*** : The summit area's alpine climate zone is an extremely challenging environment due to the combination of intense solar radiation, large diurnal temperature variations and low rainfall combined with extremely porous soils. Few plants and animals have adapted to these harsh conditions. Haleakala silversword (*Argyroxiphium sandwicense* ssp. *Macrocephalum*) and its relatives along with numerous endemic invertebrate species, such as the Aeolian wolf spider (*Lycosa* spp.), have adapted to this harsh environment.
- ***Caves (Lava tubes)****:* Several caves of varying sizes are located within Haleakala National Park. Besides their significance as cultural/archaeological sites, they provide ecological niches that have allowed the evolution of specialized and often rare arthropods (Medeiros et al. 1989). Visitor impacts and alien species are threats to cave resources.
- ***Scenic Values:*** The scenic beauty of Haleakala National Park encompasses lush rainforest, waterfalls, streams, and the beauty of a seemingly barren volcanic landscape. From the summit of Haleakala one can see the Hawaiian Island chain laid out before them. A few of the most popular scenic attractions are listed below.
    - Haleakala Crater vistas
    - Haleakala Crater wilderness areas
    - Makahiku Falls
    - Palikea Stream
    - Pools of Oheo

Threatened and Endangered Species

Haleakala is home to 26 federal threatened and endangered species (TES) with 15 TES candidates and 57 Species of Concern. Over 90% of the native biota found in Haleakala National Park is endemic to the Hawaiian Islands; nearly 50% is endemic to Maui.

Human activities, in particular introduction of alien plants and animals, has led to the extinction or severe decline of a number of native species.

- ***Haleakala Silversword****:* Silverswords are one of the few plant species thriving in the inhospitable environment of the western part of Haleakala Crater (6,500 - 10,000 feet). However alien western yellowjackets (*Vespula pensylvanica*) as well as Argentine ants (*Linepithema humile*) prey upon native insects including the primary pollinator for silverswords (Gambino 1992, Krushelnycky et al. 2004).
- ***Maui Greensword***: The greensword (*Argyroxiphium grayanum*) is confined to the small but unique bog habitat in the upper Hana rain forest (Gagne 1975). Destruction of bog habitat by pigs severely reduced greenswords and other rare endemic plants, but populations have recovered following fencing efforts.
- ***Argyroxiphium virescens***: A silversword relative, this plant once thrived just above dense rainforest at 6,000 – 7,000 ft elevation (Carr and Medeiros 1998). Habitat destruction (replacement of native forest with eucalyptus species), browsing of feral goats (*Capra hircus*) and cattle (*Bos taurus*) grazing led to the extirpation of this species from the park. Plans are underway to reintroduce this species from a surviving population.
- ***Red-flowered tree geranium***: *Geranium arboretum* is endemic to Haleakala at 6,000 -7,000 feet elevation. Populations have been reduced due to browsing by cattle and goats. In Haleakala National Park scattered individuals can be found in the Summit District (Funk 1988).
- ***Haleakala sandalwood***: *Santalum haleakalae* grows in the Summit District. Threats include rats and mice which eat the fruit of the sandalwood (Cole et al. 2000). However, its ability to reproduce vegetatively and new horticulture techniques may help the survival of this rare species.
- ***Hawaiian mints, Hawaiian Orchids, Hawaiian Lobelias***: Fencing and removal of feral pigs and plants has resulted in a dramatic recovery of Hawaiian mints, orchids, and lobelias in the upper portion of Kipahulu valley. However, in unfenced areas endemics in these plant groups have not recovered (Stone et al. 1992)
- ***Nene (Hawaiian Goose)*** Following extirpation from Maui in 1890 the nene (*Branta sandwicensis*) was reintroduced to Haleakala National Park in 1962 from captive bird stock. However they are threatened by feral cats, mongoose, and the occasional feral dog that depredate the eggs and young birds.
- ***Uau (Hawaiian Petrel)****:* Uau (*Pterodroma phaeopygia sandwichensis*) once nested throughout the park from coastal areas to the top of the mountain. Uau are the only seabirds listed as endangered in Hawaii. Haleakala is home to the world's largest protected colony of Uau; however, habitat destruction and depredation of young birds and eggs has contributed to declining populations of petrels (Hodges 1994a).
- ***Hawaiian Honeycreepers***: Five of the nine native Hawaiian honeycreepers found in east Maui are listed as endangered. The Maui nukupuu (*Hemignathus lucidus affinis*), and Maui akepa (*Loxops coccineus ochraceus*) are listed as endangered and may be extinct. The akohekohe or crested honeycreeper (*Palmeria dolei)* and Maui parrotbill (*Pseudonestor xanthophrys*) are endangered. The critically

endangered po'ouli (*Melamprosops phaeosoma*), is not present in the park but is found in the adjacent Hanawï Natural Area Reserve where protection and recovery efforts are being attempted (Casey and Jacobi 1974). As of 2005, only two individuals are known to exist, however, the Maui Forest Bird Recovery Project (pers. comm.) reports that the last po'ouli has not been sighted within the last year. The more common honeycreepers include the iiwi (*Vestiaria coccinea*), Maui alauahio or Maui creeper (*Paroreomyza montana*), apapane (*Himatone sanguinea*), and amakihi *(Hemignathus virens wilsoni*). Habitat destruction, disease, and introduced predators are the main causes for the decline of their populations, and the extinction of other species (Scott et. al. 1996).

- ***Invertebrates***: Prior to human contact, 99% of the insects present in Hawaii were endemic to the islands (Howarth and Mull 1992). Many of the native insects are important pollinators and the decline or extirpation of these species initiates a chain-reaction of further declines of native plant and animal populations. Approximately 600 native insect species and 30 snails have been recorded in or near the park. Habitat destruction and introduced predator species (rats, mice, birds and insects) are the most severe threats to endemic insects (Gambino 1982, Krushelnycky 2004). Following is a list of the rarest invertebrate groups. For some of the species in these groups their status is unknown and they may be extinct.

    - Hawaiian crickets *(Leptogryllus, Prognathogryllus)*
    - Hawaiian picture-wing *Drosophila*
    - Haleakala flightless lacewings *(Micromus)*
    - Hawaiian ground beetles *(Blackburnis, Mecyclothorax)*
    - Hawaiian long horned beetles *(Plagithmysus)*
    - Haleakala weevil *(Nesotocus, Oodemas, Proterhinus)*
    - Hawaiian damselflies *(Megalagrion)*
    - Hawaiian noctuid moths *(Agrotis, Peridroma)*
    - Hawaiian carnivorous inchworm *(Eupithecia)*
    - Haleakala flightless moth *(Hypocala velans)*
    - Hawaiian yellow-faced bees *(Hylaeus [Nesoprosopis])*

- ***Fish:*** One endemic fish species, the Oopu Alamoo (*Lentipes concolor),* is considered rare, and is found in both Pipiwai and Palikea Streams (the Oheo Gulch system).
- ***The Hawaiian Monk Seal or ilioholoikauaua*** (*Monachus schauinslandi*) occasionally visits the waters and rocky shorelines of Oheo.
- ***The Hawaiian Hoary bat or opeapea*** (*Lasiurus cinereus semotus*) has been observed at all elevations and in varying habitats throughout the park but little is known about its distribution and abundance (Duvall and Gassman-Duvall 1991).
- ***The Green Sea Turtle*** *(Chelonia mydas)* is found in waters off shore of Haleakala. The green sea turtle is a federally protected threatened species. Nesting is believed to occur in the park but there are no documenting data.

Threats & Stressors

Introduced plants and animals as well as natural phenomena pose the greatest threats to Haleakala's Natural Resources. Some examples include:

- Due to insufficient or lack of control, the continued spread of established alien plants and animals in the park poses a problem
- Invasions of alien plants and animals (brown tree snake (*Boiga irregularis*), Melastomes, grasses)
- Depredations by alien mammals, invertebrates, and potential reptilian and amphibian predators on native species
- Impacts of avian diseases on endemic avifauna
- Loss of key species such as host plants, plant dispersers and pollinators
- Potential visitor impacts in aquatic, sensitive, or wilderness areas
- Developing park infrastructure
- Increasing park visitation
- Further loss of biodiversity
- Renewed volcanic activity
- Wildfires
- Climate change
- Wind and water erosion
- Mass wasting

Water Quality Designations

In Hawaii, water bodies are classified by their designated use according to the Hawaii Revised Statutes, Section 11, Chapter 54 which contains definitions and water quality standards for each water body type with respect to desired uses. Waters which do not meet the criteria for their designated uses are considered non-supportive and, if certain conditions are met, may be reported as impaired to the Environmental Protection Agency as per requirements of the Clean Water Act, Section 303(d). Groundwater designations are being developed by the state of Hawaii, but are not available at this time. Unique or pristine water resources at Haleakala include streams, springs, and coastal waters in the Kipahulu District and sub-alpine lakes. Inland surface waters are designated "1a"; prohibiting pollution by humans and requiring maintenance of their natural wilderness character. This same protection is extended to marine waters classed as AA and marine bottom ecosystems category II. As of 2004, there are no water bodies within Haleakala that are listed as impaired by the State of Hawaii (Hawaii State DOH 2004). The Hawaii State Department of Health's water quality standards are available at http://www.hawaii.gov/doh/rules/11-54.pdf and the 2004 303(d) list for Hawaii is posted at http://www.hawaii.gov/health/environmental/env-planning/wqm/wqm.html#303pcd.

CULTURAL ISSUES

- Collection of plants for traditional use
- Harvesting of endemic freshwater species for human consumption

- Traditional farming practices within the park
- Impacts to cultural sites by visitors
- Impacts to cultural sites by vegetation
- Cataloging and management of natural history museum items

MANAGEMENT ISSUES

Park Management

Natural resource management issues at Haleakala emphasize identification and mitigation of threats in order to preserve and protect park resources.

Park management documents (General Management Plan, Resource Management Plan, etc.) are available on-line at the NPS intranet site (http://www1.nrintra.nps.gov/im/units/pacn/parks/mgmt_docs.htm). This website is available only from NPS computer networks. Inquiries about public access should be directed to the park.

Invasive species: Some of the strategies used by the resource management division to control and eradicate invasive species at Haleakala have proven effective in the protection and recovery of the native ecosystems (Loope and Medeiros 1994). Continued efforts to control and remove alien plants, mammals and invertebrates by NPS and cooperators remain an integral component of sustaining a native ecosystem.

Alien Plants: Alien plant invasions are the most significant management problem at Haleakala. Although several species are aggressively spreading throughout the park, *Miconia calvescens* is the most incipient weed currently threatening the park. *Miconia* has the ability to generate dense stands blocking out other plants thereby invading the native ecosystem. It also has a shallow root system and when located on steep slopes, contributes to erosion and landslides. Control is possible with the uprooting of smaller plants or the cutting down of larger plants and treating the stumps with herbicide (Chimera et al. 2001).

Alien Mammals: Construction of boundary fences in combination with aggressive feral animal removal strategies has effectively reduced feral pigs and goats in forest areas. Research was used to determine the appropriate pig removal method. On-the-ground control methods are the most successful techniques for the removal of ungulates in fenced areas (Diong 1982).

The rapidly increasing axis deer (*Axis axis)* population on Maui is another significant threat to the park. While the majority of the population is outside park boundaries, axis deer are occasionally leaping park fences and are spotted within park boundaries. These animals bring with them adverse effects of grazing to recovering ecosystems (Waring 1997).

Mongooses (*Herpestes auropunctatus*), feral cats (*Felis catus*), rats (*Rattus* ssp.) and occasionally feral dogs (*Canis familiaris*) are extremely threatening to endangered ground nesting Hawaiian petrel and nene populations. Trapping and toxic baits are labor-intensive but prove effective means of controlling these predators. Rats and mice (*Mus musculus*) prey on native insects and seeds of native plants, threatening plant reproduction (Cole et al. 2000). Additional funding is necessary to fully implement their predator control program in all areas of the park.

***Alien Invertebrates*:** Argentine ants and western yellowjacket wasps threaten the existence of endemic invertebrates (Gambino et al. 1987, Cole et al. 1992). Lures and toxic baiting are current control methods for ants and wasps (Loope 1987, Krushelnycky and Reimer 1996). Research to control these ants is ongoing with some assistance from the Clorox Company (Krushelnycky et al. 2004).

Visitor impacts: Visitor impacts to natural resources include cinder compaction at higher elevations, lack of waste removal (creating food sources for rodents and ants), livestock use in backcountry areas, and illegal use of fire rings at campground areas. Although some strategies have been implemented, a great need exists for funding education and interpretive programs that address these concerns.

Soundscape: Despite an informal agreement with helicopter tour companies to discontinue flights over the crater for scenic viewing, noise is audible and continues to remain a problem threatening sound quality of the native ecosystem.

Native Plants: Native plant restoration projects within Haleakala Crater have been successful in restoring pukiawe *(Styphelia sp*.), aalii (*Dodonaea sp*.), ohelo (*Vaccinium sp*.), and ulei (*Osteomeles anthyllidifolia*) from past goat browsing. In contrast, recovery of the mamane (*Sophora chrysophylla*) forest on the north slope of the crater has not occurred because of the absence of native bird populations which are needed to distribute seeds. Some recovery efforts at lower elevations in rainforests areas have also not been effective due to continued damage from feral pigs and the invasions of alien weeds.

INVENTORIES

Existing Inventories in Park

Vegetation: Inventories of bog plants were first done by C.N. Forbes in 1919. St. John and Mitchell inventoried the bogs again in 1945.

Mitchell created the first checklist of plants for the Crater District of Haleakala in 1945.

As part of the Kipahulu Expedition in 1967, Hoe inventoried the mosses of upper Kipahulu valley and Lamoureux (1967) inventoried the vascular plants. The results are published in The Kipahulu Valley Report. These studies describe numerous endemic and not previously described species.

Lamoureux and Stemmerman revisited the 1967 Kipahulu valley inventory sites in 1975 and added 2 new plants to the list. The results were published in PCSU Technical report 11.

Vascular plants in the Crater District were inventoried as part of the three-year Resources Basic Inventory program from 1975 to 1977. The inventory was confined to the crater and immediate surrounding area. The results were published as PCSU Technical Report 9 (Berger et al. 1975).

Higashino and Mizuno inventoried the Manawainui area as part of the Manawainui research project in 1976. A vascular plant checklist and vegetation map was produced for the Manawainui area as part of the Manawainui report.

In 1979 Hoe conducted an inventory of Haleakala National Park mosses. Sites were inventoried over the course of three summers previous to publication. One hundred and twenty eight moss species and varieties were collected and identified. The results were published as PCSU Technical report 25.

In 1979 an inventory of vascular plants in Puaaluu stream was published as a PCSU Technical Report 27 (Higashino and Croft 1979). The vegetation inventory was part of a larger study that included aquatic fauna quality.

In 1980 Canfield and Stemmerman inventoried vascular plants and Hoe (1980) inventoried bryophytes below 2,000 feet in Kipahulu Valley as part of the 1980 Resources Basic Inventory.

In 1980 Yoshinaga documented 47 weed species in Kipahulu Valley in an inventory of weeds published as PCSU Technical report 33.

An inventory of ferns and fern allies in the Crater District was published in 1981 as PCSU technical report 39 by Herat, Higashino and Smith. This list detailed 49 species of ferns and fern allies found in the crater during the three-year Resources Basic Inventory program from 1975 to 1977.

Smith et al. (1985) made vegetation maps for Kipahulu Valley below 700 meters. These maps and recommendations for management were published as PCSU Technical Report 53.

Higashino et al. (1988) published a checklist of 500 vascular plants found in Kipahulu Valley. Vegetation maps were compiled by Jacobi in 1989 and published as PCSU technical report 68.

An inventory of weeds and their distribution in Kipahulu Valley above 3,000 feet was conducted and published as part of a larger work on alien plants in Hawaiian natural areas (Anderson et al. 1992).

A compilation of past inventories and a comprehensive checklist of flowering plants and gymnosperms of Haleakala National Park was published in 1998 by Medeiros et al. as PCSU Technical report 120. Plant lists are updated by park staff as new plants are documented in the park.

On-going vegetation inventories include a road side inventory of weeds within the park front country and a vegetation inventory of the Kaapahu land division.

Terrestrial Vertebrates: Forest bird inventories of Kipahulu were conducted in 1967 as part of interagency Kipahulu expedition. During this survey the Maui nukupuu, previously thought to be extinct, was rediscovered (Banko 1967). Conant and Stemmerman inventoried avifauna in the Crater District in 1979. A 1981 Resources Basic Bird Inventory Below 2000 feet in Kipahulu included a bird inventory published by Stemmerman. Forest bird populations in Kipahulu Valley are inventoried each year by parks staff and periodically by the US Fish and Wildlife Service using variable circular plot (VCP) survey methods.

Berger conducted a bird inventory of the Crater District in 1975. The results of this survey are published in a Resource Basic Inventory PCSU Technical Report 9(Berger et al. 1975).

In 1976 a forest bird inventory of Manawainui was conducted by Stemmerman. Mammals and freshwater vertebrates were also inventoried in Manawainui as part of the Manawainui research project (Gon 1976a, 1976b).

A 1979 freshwater vertebrate inventory of Puaaluu stream was published as PCSU Technical report 27 (Kinzie and Ford 1979). This report also includes some water quality parameters.

A Resource Base Inventory of vertebrate species other than birds was published by Smith et al. in 1980.

Feral pig numbers in Kipahulu were inventoried using a combination of counts from animal removal within fenced units and by analyzing the freshness of ungulate signs on established transects (Anderson and Stone 1994).

Animal inventories of Kaapahu are underway to understand the number and impacts of introduced animals on the area.

Invertebrates: The 1967 Kipahulu Valley expedition included an insect inventory by Wilson. Endemic species not previously known to be in the valley were discovered.

In 1975 a Resource Basic Inventory of the Crater District was conducted and an invertebrate inventory was produced (Berger et al. 1975). Several endemic species were noted.

The 1976 Manawainui report includes an insect inventory by Villegas.

An entomological survey of Puaaluu stream was conducted in 1979 by Hardy and published as PCSU tech report 27.

Inventories of insects and myriapods (Gagne 1980), the arachnid fauna (Gon and Pinter 1980), and the land mollusks (Severns 1980) in Kipahulu Valley below 2,000 feet were published in the Resources Basic Inventory of Kipahulu Valley below 2000 feet.

In 1980 Beardsley conducted a comprehensive inventory of insects in the Crater District and published his results as PCSU technical report 31.

Surveys of Argentine ant invasions were conducted by Fellers and Fellers in 1981. The results were published as PCSU technical report 40. These inventories led to an ant monitoring program to assess the impacts of these invasive ants on native invertebrates. .

Current inventories of Crater District invertebrates are ongoing in conjunction with Argentine ant studies.

Native Frehwater Communities: Inventories of stream fauna in the Kipahulu area of the park have been conducted on several occasions. Lower Palikea, Pipiwai and Puaaluu Streams were surveyed by Kinzie in 1977; the data is published in PCSU Tech report 17 (Kinzie and Ford 1977). An inventory of Puaaluu stream fauna was published in 1979 as PCSU Technical report 27 (Kinzie and Ford 1979). A later inventory of Palikea, Pipiwai, and Puaaluu streams was conducted by Hodges (1994b), who developed standardized methods for long-term monitoring. A preliminary survey of Alelele Stream, on the south side of the park, was conducted by O'Connor in 1995. Native species of molluscs, shrimp, fish, and insects, as well as invasive species such as the Tahitian prawn (*Macrobrachium lar*), have been recorded in these streams.

Geology: Natural Resources Conservation Service (NRCS) has soil maps of all Hawaiian islands based on research conducted in the 1950s and 1960s (Cline et. al. 1955, Foote et. al. 1972). The focus of existing soil survey mapping was on agricultural land use and was generalized for other areas. NRCS has a soil temperature-monitoring program in Haleakala, started in 1975. In addition, Hawaii Civil Defense has funded research into soils mapping for seismic analysis. The University of Hawaii has a soil science department that studies Hawaiian soils extensively.

Priorities for New Inventories in Park

Vegetation**:** Recent **e**xtensive inventories of vegetation in the Manawainui area are lacking.

Invertebrates: Cave resources have yet to be inventoried in the Haleakala National Park. Cave resources include important cultural and biological elements that are unique to Haleakala. Rare snails may be present in the Kipahulu Valley but are poorly known.

***Vertebrates*:** Like all of Hawaii's National Parks, Haleakala's herpetological information is lacking. Research is needed to know the distribution and taxa of amphibians and reptiles in park lands and surrounding areas so that their impacts on park resources can be ascertained and long term monitoring can be conducted.

***Freshwater Communities*:** The streams of the Kaapahu area are thought to be high quality freshwater systems. Intensive inventories of streams in the Kaapahu area need to be completed. All freshwater communities, including bogs and ponds should be re-inventoried.

Buffer Zone Inventories

Vegetation: The mosses and vascular plants of Waihoi Valley were inventoried by Harrison in 1972 (1972b, 1972c). In 1971 Hendrickson published "Vascular flora of the northeast outer slopes of Haleakala Crater, East Maui, Hawaii". This includes the Hana and Koolau forest reserves. The south west slope of Haleakala was inventoried by Medeiros and published as PCSU Technical Report 59 (Medeiros et al.1986).

Vertebrates: A preliminary inventory of mammal, forest birds (Gon 1972), and aquatic fauna (Ibara and Conant 1972) were conducted in Waihoi Valley, a large valley adjacent to Kipahulu.

Invertebrates: Harrison (1972a) inventoried the land snails of Waihoi Valley. The results are published in the Waihoi Valley Report.

MONITORING

Existing Monitoring in Park

Vegetation: Vegetation monitoring includes annual surveys of the Haleakala silversword at fixed locations which began in 1982 (Kobayashi 1993). Monitoring of recent Koa (*Acacia koa*) defoliation in the Kipahulu valley occur to determine the extent of defoliation and the rate of recovery in these areas. Out-planted native pants are monitored regularly to assay growth and plant health. Rare plants are monitored to examine growth, phenology and recruitment.

Bog monitoring began in 1973 (Loope 1991a) and was repeated in 1977 (Yoshinaga 1977). After that point feral pig damage occurred in the bogs. Some bogs were fenced and monitoring took place annually from 1981 to 1984 (Loope 1991b). Vegetation communities in the bogs were monitored for change in 1982, 1984, 1986, and 1988 (Medeiros 1991). The reports and results of these monitoring episodes were published as PCSU Technical reports 76-78. Bog monitoring was repeated in 2001.

Jacobi (1981) monitored the changes in the Kapawiali grassland after disturbance by feral goats. This information was published as PCSU Technical Report 41. Yoshinaga (1980) monitored the changes of vegetation when areas were fenced off and feral pigs were

removed. The results of this monitoring lead to fencing off of Kipahulu valley and extensive ungulate control.

Extensive monitoring of the phenology and spread of alien plants (Medeiros et al. 1992), including the Australian tree fern (*Sphaeropteris cooperi*) is occurring.

Alien plant control teams monitor alien plant species, their location, size, and quantity, and the control methods used.

Tree line monitoring is underway to determine the effects of climate change on ecotones.

Vertebrate: Vertebrate monitoring projects at Haleakala focus on native bird species. Monitoring of Nene populations includes daily sightings for individual Nene, annual counts, and nest searches. Monitoring of Hawaiian Petrels includes monthly nest monitoring of known burrows, nest searches, and annual mark-recapture of individuals. Monitoring of forest birds in the upper portion of Kipahulu Valley occurs annually using the vcp method. Predator control as part of the Nene/Petrel protection program provides trapline catch data for rats, cats, and mongooses.

Base line avian disease monitoring was conducted in Kipahulu Valley and Kaapahu during the fall and winter of 2003. The intent of the study was to assess the extent of avian pox and malaria in these areas and identify the sources of the mosquito vectors.

Diong (1982) monitored feral pigs in Kipahulu valley and published his results as a comprehensive PhD thesis. Data from this thesis was used to implement current management strategies in Kipahulu Valley.

Previous extensive monitoring of ungulates by Yoshinaga (1980) in Kipahulu valley resulted in fencing of entire sections of Kipahulu and other areas of the park. Due to management actions, ungulate presence in fenced areas is very low to nonexistent. Current monitoring of ungulates occurs when staff checks the park's fences for feral animal control. Ungulate signs are recorded and action is taken to remove the animals.

Invertebrate: Invertebrate monitoring targets two alien species: the Argentine ant and the western yellowjacket. Monitoring the borders of Argentine ant populations began in 1998 and is ongoing. The goal is to document and contain the spread of the ant population. Monitoring of western yellowjacket activity throughout the Crater District takes place to study the spread of yellowjackets and the effectiveness of control measures.

Freshwater Communities: Monitoring methods for andromodous fishes were established and implemented for one year in Oheo Gulch and Puaaluu stream. The results of this project were published by Hodges (1994b) in PCSU technical report 93.

Water Quality: A baseline water quality data inventory and analysis was conducted at Haleakala National Park. This resulted in surface-water-quality data from six of the United States Environmental Protection Agency's (EPA) national databases: (1) Storage and Retrieval (STORET) water quality database management system; (2) River Reach File (RF3); (3) Industrial Facilities Discharge (IFD); (4) Drinking Water Supplies (DRINKS); (5) Water Gages (GAGES); and (6) Water Impoundments (DAMS). The report from this inventory provides: (1) a complete inventory of all retrieved water quality parameter data, water quality stations, and entities responsible for the data collection; (2) descriptive statistics and appropriate graphical plots of water quality data characterizing period of record, annual, and seasonal central tendencies and trends; (3) a comparison of the park's water quality data to relevant EPA and WRD water quality screening criteria; and (4) an Inventory Data Evaluation and Analysis (IDEA) to determine that Service-wide Inventory and Monitoring Program "Level I" water quality parameters have been measured within the study area. The primary goal of this project is to provide descriptive water quality information in a manner and format that is both consistent with the goals of the Service-wide Inventory and Monitoring Program and useable by park resource managers.

The USGS-WRD monitors discharge and gage height of Palikea Stream in Oheo Gulch at a dam near Kipahulu (gage #16501200) and has plans to install an additional gage in another stream inside the park.

The EPA implemented their Hawaii coastal EMAP in 2002 which included 1 randomly selected site northeast of the Haleakala coastline. Sampling will begin again in 2005 at a new set of randomly selected locations that will include open coastal areas as well as embayments in the 2004 assessment. Preliminary site selection maps indicate a sampling location very near to the 2002 site northeast of the Haleakala boundary.

Visitor impacts: Information on the number of park visitors is collected for both the Crater District and Kipahulu District. Information is collected on total vehicles, passenger number, recreational visitors, and use of backcountry and front-country camping facilities. This information is used to monitor monthly and annual fluxes in park visitation. Visitor comments are also collected via comment cards at the visitor center.

Air Quality: According to the Clean Air Act definitions Haleakala is designated as a Class I area, making monitoring for visibility mandatory. Visibility monitoring began in 1987 with slide documentations using a 35mm camera. Since 1991 visibility has been monitored by particulate sampling through the IMPROVE network (Interagency Monitoring of Protected Visual Environments). Because no adequate site could be found within the park, the IMPROVE station is located at the Olinda Endangered Species Propagation Facility, 3.8 miles northwest of the park at approximately 1,100m elevation. IMPROVE data are available at http://vista.cira.colostate.edu/improve/Data/data.htm. From 1991 to 1995 ozone was measured at this facility by the NPS Gaseous Pollutant Network. Data are available at http://www2.nature.nps.gov/air/data/index.htm.

***Climate*:** One RAWS station is located in the Kaupo Gap area. Data can be downloaded at http://www.wrcc.dri.edu/cgi-bin/raws2_pl. Furthermore, from 1991-1995, RH, precipitation, solar radiation, ambient temperature, wind speed and direction were monitored at Olinda by the NPS Gaseous Pollutant Network. In addition, The Haleakala Climate Network, HaleNet, a joint project between the USGS and the University of Hawaii operates ten weather stations on Haleakala. The stations were established between 1988 and 1992 and are located along two elevational transects on the leeward and windward sides of the mountain. Nine of the stations are within the national park boundaries. HaleNet collects data for many meteorological parameters in addition to soil moisture and soil temperature. The aim of HaleNet is to monitor climate to provide indicators of global change effects on Hawaii's climate and biota. Data are available at http://webdata.soc.hawaii.edu/climate/HaleNet/Index.htm.

Geology: The U.S. Geological Survey's Hawaiian Volcano Observatory (HVO) has an extensive monitoring program covering lava flows, deformation, seismicity and volcanic emissions. Lava, spatter, and other erupted material are sampled for geochemical and mineralogical study. Geodetic surveys are taken to precisely depict the growth of flow fields, vents and changes in ground deformation associated with volcanic activity. HVO conducts periodic leveling, GPS, EDM (electronic distance measurement) and dry tilt surveys. HVO also produces geologic maps. Dave Sherrod is updating the map of Haleakala.

Priorities for New Monitoring in Park

Vegetation: Vegetation monitoring priorities include fire fuel monitoring in dryland forest, continued weed monitoring, continued silversword monitoring, and setting up protocols for rare and endangered plant monitoring.

Terrestrial Vertebrate: No current program exists for monitoring of the Hawaiian monk Seal or Hawaiian hoary bat. A native mammal monitoring program would enable managers to better understand the necessity for management to involve decisions to be made based on the status of these species.

Buffer Zone Monitoring

Vegetation: Ungulate and weed transects are monitored in the adjacent Hanawi Natural Area reserve and The Nature Conservancy's Waikamoi Preserve. The spread and control of *Miconia* is currently monitored by a consortium of federal, state, and private management areas (Conant et al. 1997).

Terrestrial Vertebrate: The State of Hawaii together with the US Fish and Wildlife Service monitors native forest bird and introduced predator populations in Hanawï NAR.

Native Freshwater Communities: USGS-WRD research is ongoing in streams along the windward side of East Maui. Biota and water quality is examined in diverted and free flowing streams.

Air Quality**:** Particulate and gaseous monitoring equipment for the NPS air quality monitoring program is located at the Olinda Endangered Species Propagation Facility, 3.8 miles northwest of the park at approximately 1,100m elevation.

CONCLUSIONS

Haleakala National Park contains unique natural and cultural resources, diverse unique environments, a variety of rare and endangered biota, and endemic species. Isolated and pristine ecosystems allow researchers to discover plants and animals that are new to science. These unique resources are threatened by the introduction of plants and animals foreign to the Hawaiian Islands. Fires destroy unique dry land plants, goats turn ridges into barren wastelands, pigs dig up rare plants, foreign plants such as strawberry guava (*Psidium cattleianum)* and Kahili ginger (*Hedychium gardnerianum)* take over fragile native rain forests, and the threat of *Miconia* infestation grows closer to the park boundary. To ensure the preservation of these unique resources managers must continue to monitor these elements and implement aggressive actions such as fencing, ungulate control, alien plant control, and restoration to ensure that these unique species and ecological communities will exist in perpetuity.

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